CHEMICAL ALTERATION ON MARS INDICATED BY THE IRON-MANGANESE RATIO. A. S. Yen[1], B. C. Clark[2], D. W. Ming[3], D. W. Mittlefehldt[3], R. Gellert[4] and R. V. Morris[3]. [1]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Drive, Pasadena, CA 91109, Albert.Yen@jpl.nasa.gov), [2]Space Science Institute (Boulder, CO), [3]NASA - Johnson Space Center (Houston, TX), [2]Department of Physics, University of Guelph (Ontario, Canada)

Introduction: The Alpha Particle X-ray Spectrometers (APXS) onboard the Mars Exploration Rovers (MER) have measured the chemical compositions of over 400 samples on the surface of Mars. Fe and Mn are among the elements which are well established by this instrumentation. Fe^{2+} and Mn^{2+} have nearly the same ionic radii and distribute similarly in primary igneous rocks, maintaining a consistent Fe:Mn ratio. Upon exposure to an oxidative weathering environment, Fe^{3+} and Mn^{4+} are commonly formed, and elemental fractionation can occur. Thus, altered samples will typically exhibit a Fe:Mn ratio different from precursor materials.

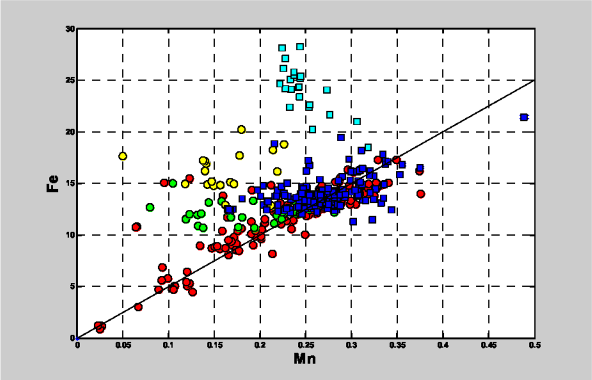

Fig. 1. Fe vs. Mn for samples analyzed at Gusev Crater (circles) and Meridiani Planum (squares). See text for descriptions of color groups.

Fe/Mn on Mars: Figure 1 shows the MER APXS dataset for Fe and Mn with the main trend displaying Fe/Mn ~ 50. There are several distinct groups of points which plot off of the main trend, and others which are significant for remaining on the trend line.

Meridiani hematite. (Cyan squares in Fig. 1). The Meridiani Planum landing site is covered with millimeter-scale hematitic concretions which have eroded out of the local rocks. These concretions formed within the layered sediments as a result of interactions of groundwater [1]. The Fe/Mn ratio >100 clearly reflects this aqueous alteration process.

Hydrothermal deposits. (Yellow circles in Fig. 1). Within Gusev Crater, a number of subsurface, light-toned soils have been excavated by the Spirit Rover. These hydrated soils are dominated by ferric sulfates, calcium sulfates, and silica. Magnesium sulfates and calcium phosphates are also inferred to be present in certain samples. The deposits exhibit the chemical signatures of nearby rocks, indicative of a fluid coupling. Taken collectively, this class of soils likely formed as condensates from hydrothermal fluids and volcanic vapors [2]. The points on Figure 1 represented by these samples show a clear enrichment in Fe relative to Mn, consistent with a chemical alteration process.

Weathered tephra. (Green circles in Fig. 1). During the climb up the West Spur of Husband Hill, Spirit analyzed a series of clastic rocks which are dominantly basaltic in composition. The Mössbauer spectrometer, which identifies iron-containing mineral phases, discovered goethite (α-FeOOH) in these rocks [3], which forms in the presence of water. Consistent with aqueous weathering of these rocks is the departure of the Fe/Mn ratio from the main trend.

Isochemically weathered rocks. (Among the red circles in Fig. 1). One rock class was identified and classified based on a chemical signature consisting of depleted Cr and elevated Ti and P. Many different rocks in this group exhibited a consistent chemical signature with Fe/Mn values along the main trend. However, the Mössbauer spectrometer showed that the iron oxidation state varied significantly: Fe^{3+}/Fe_{total} ranged between 0.4 and 0.9 [3]. These rocks were weathered, but the alteration process appears to have been a closed chemical system with the exception of oxygen. Alteration did not involve sufficient liquid water to mobilize cations and fractionate Fe and Mn.

Martian dust. (Among the red circles and blue squares in Fig. 1). Well-established on the main trend are the data points which represent the typical basaltic soils found at both Gusev and Meridiani. This is an indicator that these materials are not products of extensive chemical weathering. Alteration of the finest grained component and the production of the nanophase ferric oxides which give these soils their distinctive color did not involve substantial water. Alteration likely occurred as a result of interactions with acidic volcanic emissions containing S and Cl [4].

Conclusion: The Fe/Mn ratio of analyzed martian samples, when used appropriately in conjunction with other available data, is useful for constraining the extent of chemical alteration.

References: [1] McLennan S. M. et al. (2005) *EPSL, 240,* 95-121. [2] Yen A. S. et al. (2008) *JGR, 113,* E06S10. [3] Morris R. V. et al. (2006) *JGR, 111,* E02S13. [4] Yen A. S. et al. (2005) *Nature, 436,* 49-54.